REMARKS

Claims 1-3 have been amended to recite the characteristics of the scintillator of the invention and to delete references to the light guide and cylindrical configuration. These latter features have been added to dependent claims 8 and 9 of newly added dependent claims 4-9. Support for the amendments to claims 1-3 can be found in Table 1 on page 3 and in paragraphs [0015], [0026], and [0032] of the specification, for example. Support for claims 4-8 can be found in paragraph [0026] on page 11 of the specification, and support for claim 9 can be found in Figure 1. No new matter has been added. Upon entry of this amendment, claims 1-9 will be in the application.

Claim rejections

Claims 1and 2 were rejected under 35 U.S.C. §103(a) as allegedly being obvious over Moses (US 5,015,860) in view of Andreaco et al. (US 6,362,479). Claim 3 was rejected under 35 U.S.C. §103(a) as allegedly being obvious over Casey et al. (US 4,743,764) in view of Moses and Mullani (US 4,559,597). These rejections are respectfully traversed for the reasons given below.

The claimed invention relates to a PET detector and a corresponding PET scanner and scanning system. The claimed PET detector includes a plurality of photomultiplier tubes and a scintillator comprising a plurality of crystals. In the exemplary embodiments, the scintillator has a decay time constant $\tau \leq 35$ ns and a light output at least equal to the light output of NaI(Tl). Also, the scintillator crystals and the photomultiplier tubes are arranged respectively peripherally around a cavity for accepting a patient. The PET scanning system further includes a time stamp circuit and a processor for calculating time-of-flight (TOF) of gamma rays that pass through a patient in the cavity that accepts the patient. The TOF of the gamma rays is then used in the reconstruction of images of the patient. Such a PET detector and scanning system are not shown or suggested by the references cited by the Examiner.

Moses discloses a radiation detector containing a mixture of LaF_3 and CeF_3 to create a scintillator with properties different than a pure CeF_3 scintillator, a known scintillator in 1990. Moses does not teach one skilled in the art how to develop a $LaBr_3$ scintillator, a $LaCl_3$ scintillator, or any other scintillator that combines a fast decay time with a high light output as claimed. Instead, Moses discloses that pure LaF_3 does not scintillate, whereas the

combination of LaF_3 with CeF_3 does scintillate. For example, 90% LaF_3 with 10% CeF_3 has 90% the light output of pure CeF_3, but the decay is split into two components (fast=18 ns and slow=30 ns), whereas 99% LaF_3 with 1% CeF_3 has 50% the light output of pure CeF_3 with one fast component (18 ns vs. 27 ns for pure CeF_3). Thus, one property of the combined scintillator is worse than the corresponding property of a pure CeF_3 scintillator (light output), while another property of the combined scintillator is better (decay time). In comparison to the 99% LaF_3/1% CeF_3 scintillator taught by Moses, a $LaBr_3$ scintillator has slightly poorer stopping power (0.47/cm vs. 0.53/cm), similar decay time (between 18 ns and 35 ns depending on the percentage of cerium dopant), but a very significant advantage in light output - 64,000 photons/MeV vs. 800 photons/MeV – a factor of 80 improvement. Thus, the combination of properties of $LaBr_3$, for example, are very different from those of LaF_3/CeF_3, and could not be predicted (or taught) by knowing the properties of LaF_3/CeF_3. Applicant submits that the development of a LaF_3/CeF_3 scintillator as taught by Moses would not have lead one skilled in the art to develop a $LaBr_3$ scintillator or any other scintillator with the claimed high light output and fast decay. Moses provides no information describing the methodology of growing the scintillator or any teachings as to why certain elements combine to make a good scintillator. In fact, it took 10 additional years before $LaBr_3$ or $LaCl_3$ scintillators were developed.

Applicant notes that the low light output of LaF_3/CeF_3 scintillators does not preclude its use in PET, but it does require a direct coupling of a scintillator to a PMT as shown in Figure 1 of Moses. This limits the size of the crystal to the size of the PMT, which generally leads to very poor spatial resolution (*i.e.* large crystals) unless a solid state light sensor is used instead of a PMT. In comparison, the very high light output of $LaBr_3$ or $LaCl_3$ in accordance with the invention allows the encoding of very small crystals with large PMTs, by, for example, using a light guide to distribute the light to multiple PMTs. In an example embodiment, 4-mm x 4-mm crystals and 50-mm diameter PMTs are used, thus providing an encoding ratio (crystals:PMT) of about 100:1. This type of detector leads to very high spatial resolution in PET. In addition, a 3D PET scanner such as that described requires very good energy resolution to reject scattered radiation, which can be achieved with $LaBr_3$ or $LaCl_3$ but not with LaF_3/CeF_3 due to its low light output. In other words, the light output of LaF_3/CeF_3

scintillators was much too low to have suggested or permitted the use of the scintillator and PMTs about a patient cavity for a high resolution 3D PET scanner as claimed.

Despite the fast decay of LaF_3/CeF_3 scintillators, the light output is very low ($1/80^{th}$ that of $LaBr_3$). Good timing resolution requires a combination of fast decay and high light output – more specifically a large number of photons in the leading edge of the scintillation pulse to get an accurate time stamp from a timing discriminator. Therefore, the timing resolution with LaF_3/CeF_3 (not described by Moses) would not be good enough for time-of-flight (TOF) PET and thus would not have been considered by those skilled in the art for TOF PET. TOF is never even mentioned by Moses.

In summary, while Moses disclosed that it is possible to build a PET scanner with a plurality of CeF_3 or LaF_3/CeF_3 detectors, such a PET scanner would have poor spatial resolution, poor energy resolution, and would not have time-of-flight capability. In contrast, the properties of $LaBr_3$ and $LaCl_3$ (Table 1) (which do not depend on knowledge of LaF_3/CeF_3) allowed the inventors to develop a 3D PET scanner with high spatial resolution, excellent energy resolution, and TOF capability. Moses does not provide such teachings.

The Examiner cites the Andreaco et al. patent for a teaching of a light guide arranged around the cavity for accepting a patient. The Examiner further concludes that one skilled in the art would have modified the Moses system to include such a light guide. Applicant respectfully disagrees.

Andreaco et al. teach that two scintillators with different decay times may be combined in two layers so as to allow measurement of for both SPECT (low energy) and PET (high energy) gamma rays. This is done through pulse shape discrimination. By using two layers, the performance for each mode (SPECT vs. PET) is less compromised than by using a single layer. Also, this technique allows depth-of-interaction measurement to reduce the parallax effect which degrades image spatial resolution. The description covers different types of light guides (active and passive) but all are similar to the slotted light-guide described in the Casey patent (see below). In any case, Andreaco et al. do not teach how to build a PET scanner including the claimed scintillator, light guide and PMTs disposed peripherally around a patient cavity as claimed in new dependent claim 8. Andreaco et al. also do not disclose a TOF detector; in fact, the 2-layer design disclosed by Andreaco et al. may not work well for TOF – certainly not with NaI(Tl) as one of the layers. Moreover, as

noted above, the low light output of the scintillator of Moses would have precluded the use of such a light guide in the claimed configuration.

Accordingly, even if one skilled in the art would have been motivated to combine the teachings of Moses and Andreaco et al. as the Examiner suggests, the claimed invention would not have resulted. No teaching of the claimed scintillator is provided in either reference, and no teaching of the claimed geometry for the scintillator in combination with a light guide and PMTs is provided. Absent such teachings, the invention of claims 1-9 is believed to be novel and nonobvious over the teachings of Moses and Andreaco et al. taken separately or in combination. Withdrawal of the rejection of claims 1 and 2 and allowance of claims 1-9 is respectfully solicited.

The shortcomings in the teachings of Moses and Andreaco et al. are not overcome by Casey et al. Casey et al. disclose a detector to encode many crystals with fewer PMTs. Figure 4B in Casey et al. shows that a 2-D detector consists of 32 crystals (8 by 4) encoded by 4 PMTs. A slotted light-guide is used to distribute the light from each crystal proportionately to each PMT. A block detector requires that the crystal array (shown to be 8 by 4) is aligned with the PMT array (shown to be 2 by 2). The slotted light guide controls the amount of light from each crystal to be shared with the four PMTs in such a way as to best discriminate the position of the crystal within the array. This precise method of light sharing is needed for a scintillator such as BGO that has low light output, since the statistics are poor. In addition, this method compensates for the fact that light output from the crystal varies as a function of position within the array – *e.g.* the light from a center crystal is highest and is split among all four PMTs, while a crystal in the corner is lowest and is sent only to one PMT. The variation in light output among all positions can be as large as a factor of three. This makes it difficult to achieve good energy resolution, and would also make it difficult to use such a design for a TOF detector. In fact, even with a reasonably fast scintillator (such as LSO) the block detector has not been shown to be a good TOF detector.

The claimed PET detector in the claimed PET scanning system of Figure 3 is significantly different than that taught by Casey et al. The claimed PET detector uses a scintillator comprising a plurality of crystals whereby the scintillator has a fast decay time constant "$\tau \leq 35$ ns" and a high light output "at least equal to the light output of NaI(Tl)." In an exemplary embodiment, the scintillator crystals are optically coupled through a continuous

(unslotted) light guide to a hexagonal array of large PMTs. The crystal array does not need to be any particular size, nor does it need to be aligned with the PMT array. The light guide distributes the light to the PMTs in a manner determined by the thickness of the light guide. Such an arrangement as now set forth in independent claim 3 and more particularly in dependent claim 8 is not taught by Casey et al., Moses or Andreaco et al.

Thus, Casey et al. also fail to teach one skilled in the art how to build a time-of-flight detector, specifically how to build a PET detector having a scintillator with the claimed fast decay time and high light output. Accordingly, if the teachings of Casey et al. could have been combined with the teachings of Moses and/or Andreaco et al., the claimed PET scanning system would not have resulted.

Finally, the Examiner cites Mullani as allegedly teaching a PET imager with a time stamp circuit and a processor as set forth in claim 3. Applicant respectfully disagrees. Mullani teaches that TOF may allow one to build a PET scanner with multiple rings of detectors and to use the cross-coincidences among all rings to improve sensitivity. The TOF information allows one to approximately place the event in the most likely position - in both the transverse (in-plane) and axial (out-of-plane) directions. The data can then be reconstructed with a 2D algorithm, slice by slice – although with TOF information the 2D reconstruction would be modified (*e.g.* confidence-weighted backprojection). Mullani describes a method to use the TOF information to reconstruct the 3D data by first sorting into 2D planes. 3D image reconstruction is much more computationally intensive than 2D image reconstruction due to the increased number of coincidence lines. Mullani's invention takes advantage of the TOF information by sorting the 3D data into 2D planes and reconstructing with a 2D algorithm (but still using the TOF information in 2D). Such teachings are not relevant to the invention as claimed in claim 3 for Mullani does not overcome the afore-mentioned shortcomings in the teachings of Moses, Andreaco et al., and Casey et al. Withdrawal of the rejection of claim 3 is solicited.

New dependent claims 4-9 are believed to be allowable by virtue of their dependence upon allowable independent claims 1 and 2. In addition, claims 4-9 are believed to set forth novel features not cited by any of the cited references in any proposed combination. Allowance of claims 4-9 in addition to claims 1-3 is thus solicited.

Conclusion

The invention of claims 1-9 is not shown or suggested by the cited prior art. The present patent application is thus believed to be in condition for allowance, and a Notice of Allowability is respectfully requested.

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